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For: **CMOS IMAGE SENSORS**

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Sir:

Transmitted herewith is a certified copy of the
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Respectfully submitted,

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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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CMOS Image Sensors

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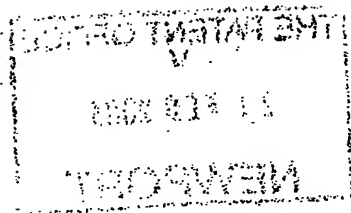
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1 CMOS Image Sensors

2

3 The invention relates to semiconductor image
4 sensors, and in particular to such sensors commonly
5 termed CMOS image sensors.

6

7 CMOS image sensors typically comprises a matrix of
8 pixels each containing a photosensing part, such as
9 a photodiode, and other active or passive parts.

10 CMOS image sensors are made with the same standard
11 CMOS fabrication processes used in mainstream high-
12 volume wafer fabrication plants to produce IC
13 devices, such as micro-processors, micro controllers
14 and DSPs. This means that signal processing and
15 control circuits may be integrated on the same
16 semiconductor material as the photosensing and other
17 parts, thereby providing a low cost integrated
18 imaging device. Also, CMOS image sensors can benefit
19 from the advances made in the mainstream
20 semiconductor industry.

21

1 Increasingly, in what is called a silicide-type
2 process, silicide is applied to IC devices as part
3 of a CMOS fabrication process. The formed silicide
4 has the effect of reducing parasitic resistance and
5 improving switching speed. However, refractory
6 metal silicide suppresses transmission of light and
7 is therefore unsuitable for application to devices
8 including photosensing parts.

9
10 US 6,160,282 discloses a CMOS image sensor pixel
11 where the photosensing parts have been protected by
12 silicon oxide from the formation of silicide. The
13 sensor thereby gains from the improvements
14 associated with silicide formation on some non-
15 photosensing parts.

16
17 US 5,903,021 discloses how the performance of a CMOS
18 image sensor pixel may be improved by partially
19 "pinning" the photo-diode. Pinning involves
20 covering part of the surface of the photo-diode with
21 a layer of semiconductor material of the same type
22 as the substrate. As a consequence, the potential of
23 the surface is pinned to the potential of the
24 substrate. This increases the quantum efficiency of
25 the photo-diode in addition to reducing its dark
26 current and improving its blue colour response,
27 which is normally the weakest of all the colour
28 responses. As a result, the pixel performs to a
29 high standard.

30
31 It has been shown by I. Murakami et al in an article
32 entitled "Technologies to Improve Photo-Sensitivity

1 and Reduce VOD Shutter Voltage for CCD Image
2 Sensors" (IEEE Trans. Electron Devices, vol. 47,
3 2000, pp. 1566-1572), that quantum efficiency of a
4 photodiode in an image sensor can be improved by
5 applying an anti-reflective coating to increase
6 light coupling.

7
8 Photo response uniformity is an important parameter
9 for image sensors. This parameter can be limited by
10 the uniformity of the photo-diode capacitance from
11 pixel to pixel within the sensor matrix. Variation
12 of the patterning of the implants within the pixel
13 can also cause a reduction in the matching of photo
14 response between pixels. One technique used to
15 improve this matching is a self-aligning technique
16 where a single master layer is used to define the
17 implant areas. Each of the different implant areas
18 may then be selected by use of a lower tolerance
19 select mask while maintaining the good matching
20 achieved by use of a single master layer.

21
22 According to one aspect, the invention provides a
23 semiconductor image sensor comprising at least one
24 pixel having a photosensing part, characterised in
25 that the photosensing part has a coating which
26 performs a dual function.

27
28 Preferably, at least one of the functions of the
29 dual function is a fabrication function. Further
30 preferably, the fabrication function is the
31 prevention of silicide formation

32

1 Alternatively or additionally preferably, at least
2 one of the functions of the dual function is an in-
3 use function. Further preferably, the in-use
4 function is anti-reflection.

5

6 The constituents and thickness of the coating may be
7 optimised for maximum response at a particular
8 wavelength.

9

10 Preferably, the photosensing part comprises a photo-
11 diode. Further preferably, the photodiode is a
12 pinned photodiode. Additionally preferably, the
13 pinned photodiode is partially pinned.

14

15 According to another aspect, the invention provides
16 a method of making a semiconductor image sensor
17 comprising forming at least one pixel having a
18 photosensing part, characterised by coating the
19 photosensing part with a coating which performs a
20 dual function.

21

22 The invention will now be described, by way of
23 example, with reference to the figures of the
24 drawings in which:

25

26 Fig.1 is a cross sectional side view of a pixel in
27 an image sensor according to an aspect of the
28 invention.

29

30 Fig. 2(a) is a cross sectional side view of a pixel
31 in an image sensor with implant areas and silicon

1 oxide islands formed and a silicon dioxide layer and
2 a silicon nitride layer.

3

4 Fig. 2(b) is a cross sectional side view of a pixel
5 in an image sensor as described in Fig.2(a) with a
6 layer of photoresist applied.

7

8 Fig. 2(c) is a cross sectional side view of a pixel
9 in an image sensor as described in Fig.2(b) after
10 exposure to a suitable light source.

11

12 Fig. 2(d) is a cross sectional side view of a pixel
13 in an image sensor as described in Fig.2(c) after
14 removal of the unexposed photoresist.

15

16 Fig. 2(e) is a cross sectional side view of a pixel
17 in an image sensor as described in Fig.2(d) after
18 removal of the silicon nitride layer and silicon
19 dioxide layer not below the exposed photoresist.

20

21 Fig. 3(a) is a cross sectional side view of a pixel
22 in an image sensor with a coating over the
23 photosensitive area formed.

24

25 Fig. 3(b) is a cross sectional side view of a pixel
26 in an image sensor as described in Fig.3(a) with a
27 layer of titanium deposited.

28

29 Fig. 3(c) is a cross sectional side view of a pixel
30 in an image sensor as described in Fig.3(b) with a
31 layer of silicide formed everywhere except over the
32 photosensitive area.

1
2 With reference to Fig.1, a pixel indicated generally
3 at 101 is formed on a p-type substrate 118 with a
4 photosensing part 102 and an active part 104. The
5 photosensing part 102 comprises a partially pinned
6 photo-diode formed from an n-well 116 within the
7 substrate 118 and a p-type pinning layer 106
8 partially covering the n-type well 116. The active
9 part 104 comprises an NMOS transistor formed from
10 two spaced apart, highly doped n-type implants 110
11 in a p-type well 114. The n-type well 116 is
12 positioned so as to connect the photo sensing and
13 active regions 102, 104. The p-type pinning layer
14 106 has an anti-reflection coating 130 of silicon
15 nitride on silicon dioxide. In use of the pixel
16 101, this increases light coupling so as to improve
17 the photo-diode quantum efficiency. During
18 fabrication of the pixel 101, which involves the use
19 of a salicide-type process, the anti-reflection
20 coating 130 prevents the formation of salicide over
21 the photo-diode. Thus, the coating 130 has a dual
22 function.

23
24 With reference to figure 1, a pixel 101 is
25 fabricated, prior to the creation of the implant
26 regions 106 and 110 and application of the coating
27 130, using the well known self-alignment technique.
28 This technique involves creating lands 108 of
29 silicon oxide between parts of the pixel 101. The
30 lands 108 are formed on the surface of the pixel 101
31 by a stepwise process involving photolithography,
32 using a single master mask layer. The end result of

1 this process is that the surface of the pixel 101 is
2 blocked by silicon nitride everywhere apart from the
3 areas where the lands 108 are to be formed. The
4 pixel 101 is then heated in an oxygen atmosphere
5 such that silicon oxide is formed in the unblocked
6 regions. The silicon nitride blocking is
7 subsequently removed, leaving the silicon oxide
8 lands 108.

9
10 The creation of the lands 108 at this stage in the
11 process allows the use of the edges of the lands 108
12 as reference axes. When each pixel 101 is created
13 the width of the central land 108, in particular, is
14 kept constant, through use of the same master mask
15 layer. This ensures accurate spacing between the N⁺
16 region 110 of the active part 104, which is
17 connected to the photosensitive part 102, and the
18 pinning part 106. Ensuring the accurate spacing
19 between these parts is critical for pixel to pixel
20 uniformity.

21
22 Two separate masks (not shown) are used for the
23 creation of the implant parts 106, 110. Each of
24 these masks covers the entire pixel surface except
25 the specific implant part 106, 110. The width of the
26 central land 108 allows for some error in placement
27 of the appropriate mask on the pixel without
28 compromising the uniformity between pixels.

29
30 The coating 130, as shown in figure 1, is formed in
31 a stepwise process as shown in figure 2. Figure 2a
32 shows a pixel 201 after the first step of the

1 process, wherein a thin silicon dioxide layer 205 is
2 formed over the exposed silicon. This silicon
3 dioxide layer 205 may be formed by a number of
4 different standard methods including thermal
5 oxidation or chemical vapour deposition. On top of
6 the silicon dioxide layer 205, a silicon nitride
7 layer 207 is formed. Formation of the silicon
8 nitride layer 207 is made by use of a chemical
9 vapour deposition (CVD) process. This may be either
10 thermal or plasma enhanced CVD. The silicon dioxide
11 layer 205 and the silicon nitride layer 207 together
12 form a coating 230.

13
14 The thickness of the coating 230, over the
15 photosensitive part 202, is controlled by the length
16 of time of the CVD deposition to give an optimum
17 thickness of 300\AA ($\pm 50\text{\AA}$) of the silicon nitride
18 layer 207 and 250\AA ($\pm 50\text{\AA}$) of the silicon dioxide
19 layer 205. However, because the coating has a dual
20 function, the thickness of the coating 230 chosen is
21 a balance between being thick enough to prevent
22 silicide formation and being the correct optical
23 path length to ensure an anti-reflective surface in
24 the desired wavelength range. The peak transmission
25 through the coating 230 is normally set to be a
26 maximum at a wavelength of 450nm . This acts to
27 increase the quantum efficiency of the sensor to
28 blue light thereby improving colour camera
29 performance.

30
31 A layer of photoresist 220 is then applied to the
32 whole surface of the pixel 201 (figure 2b). A mask

1 224 is then placed over the pixel 201 such that the
2 photosensitive part 202 is not covered (figure 2c).
3 The pixel 201 is then illuminated through the mask
4 224 so as to expose the uncovered photoresist 228.
5 The light source 222 and the mask 224 are then
6 removed as well as the unexposed photoresist 226. An
7 etching step is used to remove the coating 230 from
8 the surface of the pixel 201, everywhere apart from
9 over the photosensitive part 202, which is protected
10 from the etching step by the exposed photoresist
11 228. The photoresist 228 is then removed using a
12 standard photoresist strip process, leaving a pixel
13 101 as shown in Figure 1.

14

15 The silicide type process involves forming silicide
16 on the surface of the pixel. The silicide has the
17 effect of reducing parasitic resistances and
18 therefore is desirable. However, silicide hampers
19 light transmission and so is unsuitable for
20 application to a photosensing part.

21

22 With reference to Figure 3a, a pixel 301 is shown
23 which has gone through the stepwise process required
24 to provide the coating 330. A titanium layer 350 is
25 deposited over the entire surface of the pixel 301
26 as shown in Figure 3b. In a thermal treatment the
27 titanium reacts with exposed silicon to form
28 silicide 352 but does not react with the silicon
29 nitride layer 307 or silicon dioxide layer 308.
30 Unreacted Titanium deposited on the silicon nitride
31 coating and silicon dioxide may be removed in a wet.

1 processing step, as shown in Figure 3c, leaving the
2 coating to come in use as an anti-reflective layer.

1 Claims

2
3 1. A semiconductor image sensor comprising at least
4 one pixel having a photosensing part, characterised
5 in that the photosensing part has a coating which
6 performs a dual function.

7
8 2. A sensor as claimed in Claim 1, wherein at least
9 one of the functions of the dual function is a
10 fabrication function.

11
12 3. A sensor as claimed in Claim 2, wherein the
13 fabrication function is preventing silicide
14 formation

15
16 4. A sensor as claimed in any of Claims 1 to 3,
17 wherein at least one of the functions of the dual
18 function is an in-use function.

19
20 5. A sensor as claimed in Claim 4, wherein the in-
21 use function is anti-reflection.

22
23 6. A sensor as claimed in any preceding Claim,
24 wherein the photosensing part is a photo-diode.

25
26 7. A sensor as claimed in Claim 6, wherein the
27 photo-diode is pinned.

28
29 8. A sensor as claimed in Claim 7, wherein the
30 photo-diode is partially pinned.

31

- 1 9. A method of making a semiconductor image sensor
2 comprising at least one pixel having a photosensing
3 part, characterised by coating the photosensing part
4 with a coating which performs a dual function.
5
- 6 10. A method as claimed in Claim 9, wherein at least
7 one of the functions of the dual function is a
8 method of fabrication function.
9
- 10 11. A method as claimed in Claim 10, wherein the
11 method of fabrication function is to prevent
12 silicide formation
13
- 14 12. A method as claimed in any of Claims 9 to 11,
15 wherein at least one of the functions of the dual
16 function is an in-use function.
17
- 18 13. A method as claimed in Claim 12, wherein the in-
19 use function is anti-reflection.
20
- 21 14. A method as claimed in any of Claims 9 to 13,
22 further characterised by involving a self-aligning
23 technique.
24
- 25 15. A method as claimed in Claim 14, wherein the
26 photosensing part is a photo-diode and further
27 characterised by pinning the photo-diode.
28
- 29 16. A method as claimed in Claim 15, wherein the
30 photosensing part is a photo-diode and further
31 characterised by partially pinning the photo-diode.

1 ABSTRACT

2
3 A CMOS image sensor 1 and method of making such
4 sensor uses a coating 11 over the photosensing parts
5 which performs a dual function. In fabrication the
6 coating prevents the formation of silicide, which is
7 not optically opaque, on the photosensing parts. In-
8 use the coating helps to couple light on to the
9 photosensing parts and therefore acts as an anti-
10 reflective layer. The method of fabrication uses a
11 self-aligning technique, which ensures pixel to
12 pixel uniformity.

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FIGURE 1/3

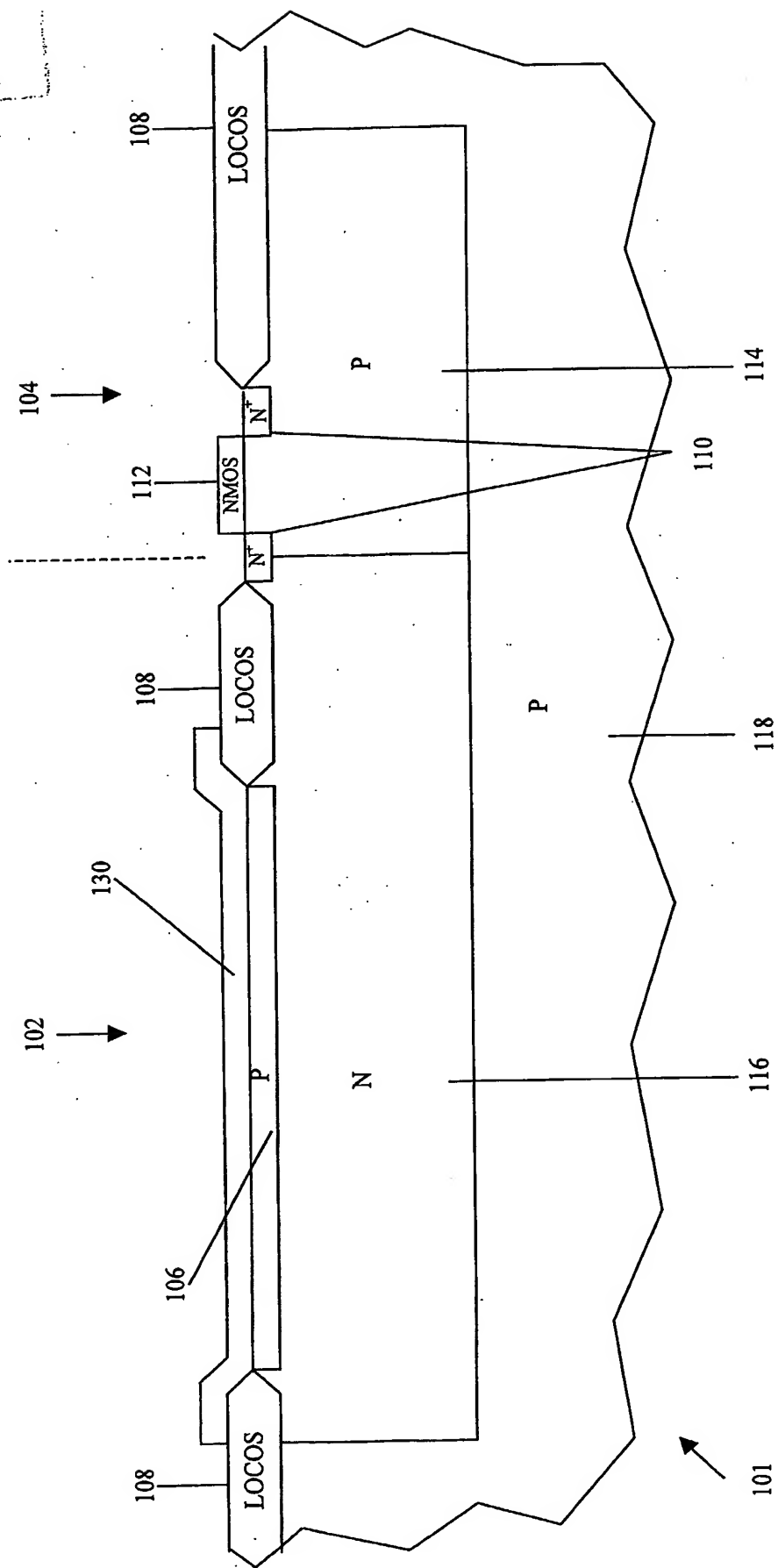
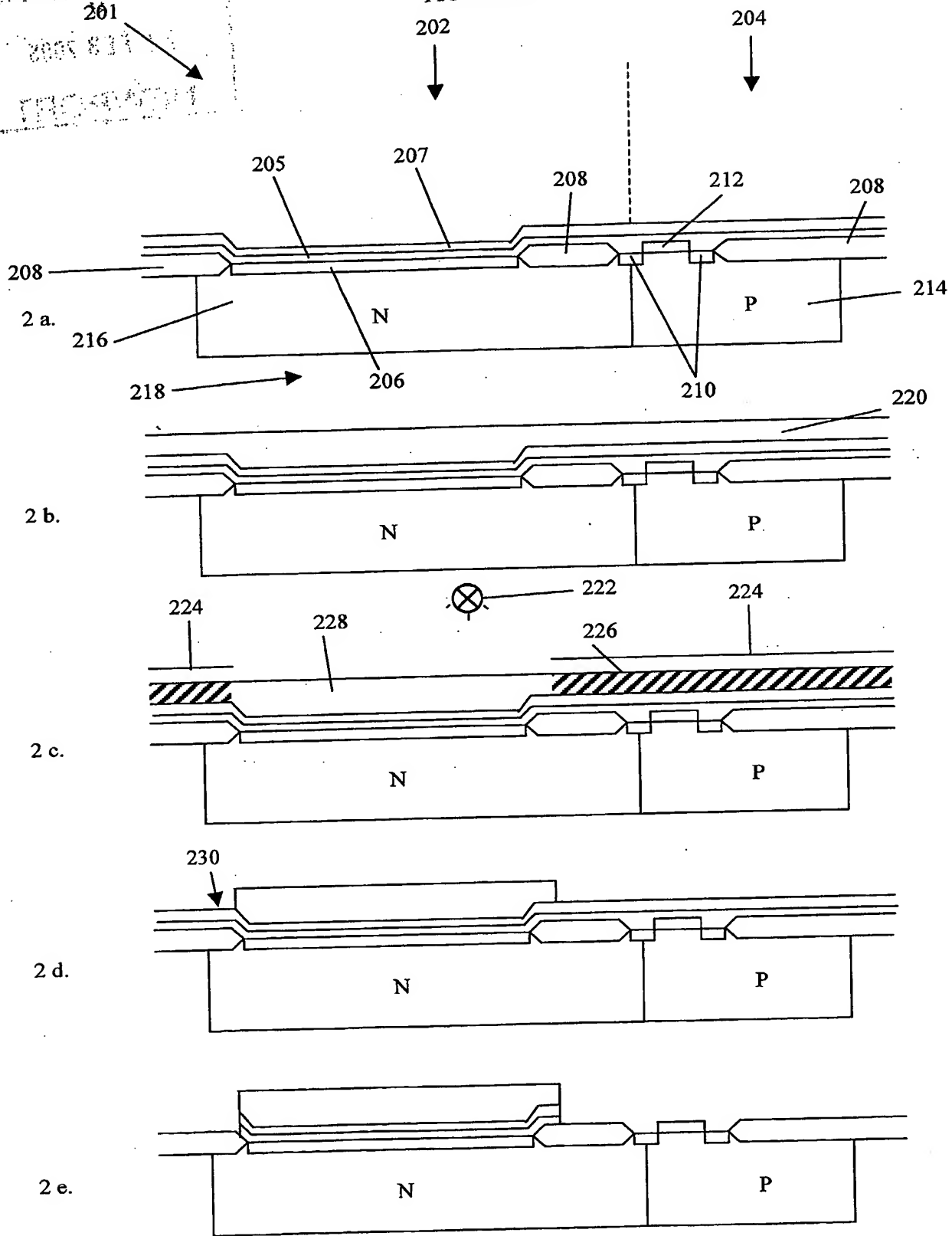
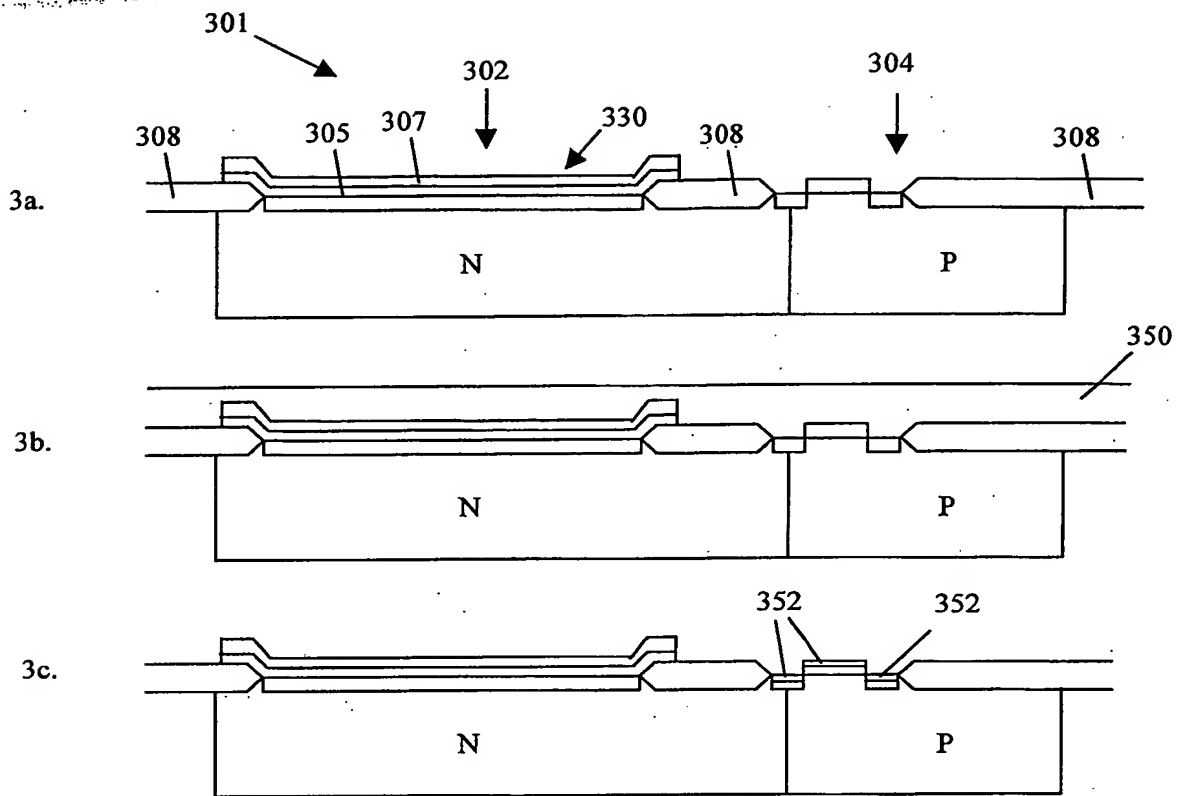


FIGURE 2/3



TOPTO TASTA ENT
8002 037 13
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FIGURE 3/3



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